Identification of Critical Factors in Large Crisis Decision Making Processes using Computational Tools: The case of ATHENA

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Identification of Critical Factors in Large Crisis Decision Making Processes Using Computational Tools:
The Case of ATHENA

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ABSTRACT

This article aims to present a social media-based system that coordinates the responses of the authorities in a large crisis. The article performs extensive review of literature in order to identify decision making approaches in crisis situations and the different factors that affect these approaches. It also presents the ATHENA Crisis Management system which is based on a platform that makes combined use of data mining algorithms for the purpose of analysing large amounts of data received through the Social Media during and after a large crisis. A number of conclusions are drawn on the identification of different types of factors that impact large crisis decision making.

KEYWORDS

ATHENA, Categorisation, Concept, Crawling, Credibility, Crisis, Decision, Factors, Sentiment

INTRODUCTION

The severity of the consequences of a large crisis (e.g. earthquake, flooding, terrorist actions) requires a thorough and well-designed crisis management and decision-making process. In many occasions in the past, bad handling of a crisis resulted to additional problems. Crises tend to be characterized by stresses and demands. Specifically, crises are characterized by high impact events and choices both in political and ethical level. Crises involve situations where national, organizational, and personal values are in doubt. Furthermore, possible bad handling of a crisis situation can profoundly impact political perceptions and choices for years or decades to come. A crisis is characterised by the following factors: a threat to basic values, urgency and uncertainty (Stern, 2003). Risk, uncertainty and collective stress need to be integrated to a broader understanding of how governments and decision makers respond to crisis situations. Pearson and Clair (1998) suggest ambiguity and urgency are the two main characteristics of a crisis and they affect the way leaders take decisions. Also, response uncertainty and time pressure characterise a crisis (Billings, Milburn & Schaalman, 1980).

During a large crisis, such as the 11th of September, the pressure on crisis decision makers was extremely high and the intensity on taking decisions during such times was unimaginable. The decisions made during such a crisis had to be instant and as much as accurate as possible. Planes in the air were advised to land to the closest airport while subway trains stopped and as a result a number

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between 3000 and 5000 lives were saved (Associated Press, 2001). Tens of thousands of people were evacuated from the targeted buildings and from those in close vicinity. The WTC tragedy resulted in the death of nearly 3000 people, the relocation of 1000 firms and put over 100,000 out of work (Bram et al., 2002; New York Metropolitan Transportation Council, 2002). In these circumstances, leaders with crisis management and leadership talents are very highly valued (Hymowitz, 2001) as a large amount of information associated with the crisis may be inaccurate or simply unavailable. Decisions also need to be made considering the different factors, constraints and consequences.

Crisis decision making must be a very carefully designed process and its significance is shown by the amount of research realised to improve it. Janis and Mann (1977) have presented a number of criteria that need to be followed in order for decision making during a crisis to be efficient. The first of these criteria is the identification of the objectives that need to be achieved by the decision(s) taken and the specification of the major requirements of a successful choice. The second criterion is the generation of a comprehensive list of alternatives while the third criterion is the wide search of the relevant information with which the quality of the alternatives can be determined. The fourth criterion is the accurate elaboration of information relevant to the assessment of the alternatives and the fifth criterion is the re-evaluation of the advantages and disadvantages of the alternatives. During a large crisis, such as 09/11, a crisis decision maker has to face a number of factors, both cognitive and emotional (Kleinmuntz, 1990) but also a number of external parameters, both in organisational and environmental level.

There are different types of crises and different decision-making processes. Also, different factors affect these processes. Snowden and Boone (2007) suggest that a new form of leadership and management should be formed and be based on complexity science. The reason for this is that circumstances change and as they become more complex, any simplifications can fail. As a result, good leadership is a not a one-size-fits-all proposition. Complexity is more a way of thinking rather than a new way for working with mathematical models. For this purpose, the Cynefin framework has been developed and this framework allows crisis leaders to see things from different perspectives, analyse complex information and address real-world problems. The framework uses different domains and each of them requires different actions. Simple and complicated contexts assume that there is order and right decisions can be based on facts. Complex and chaotic contexts are unordered, and any decision making is based on emerging patterns. The fifth context (disorder) is characterised by cacophony. In this case, the situation must be broken down into different segments and assign each of them to one of the four other contexts (Snowden & Boone, 2007).

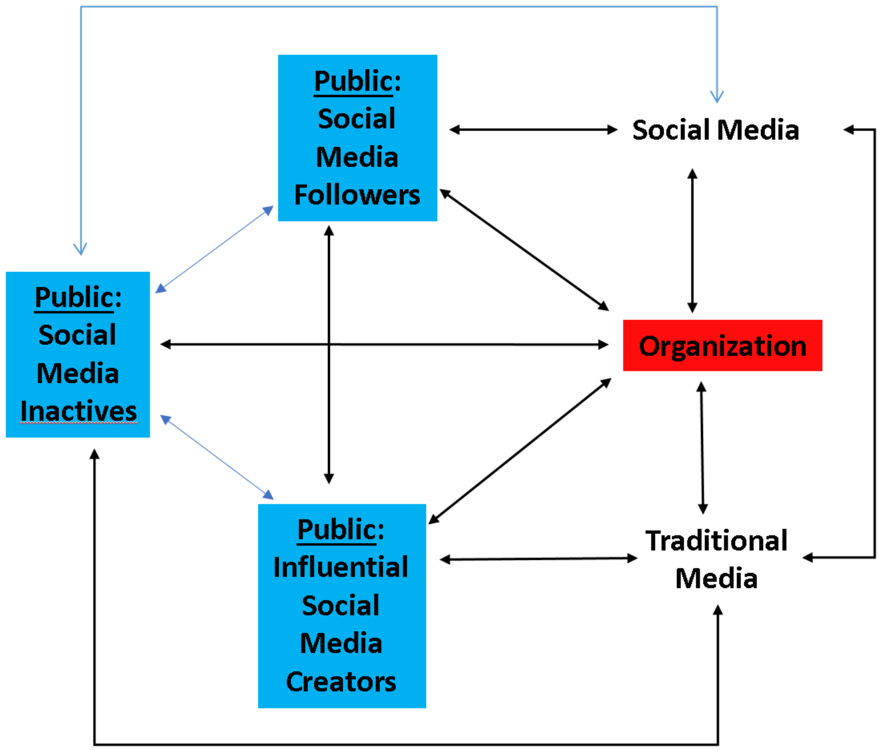
Overall, crisis management is a very important function of leadership in public, private, and non-profit organizations. It is very challenging even to organizations used to fast-paced operations, such as first responders (Stern, 2014). Successful crisis management does not consider only the different factors that directly affect the crisis decision makers but also the audience of the crisis decision makers, in the case of a crisis, this audience are the citizens. Especially nowadays with the continuous use of the Social Media, crisis communication has taken another form. Specifically, more factors have direct impact on this communication. This can be shown in Figure 1.

This paper focuses on the identification of the factors that affect large crisis decision making and the impact these factors have on the way crisis decision makers make decisions. The paper provides a review of the main crisis decision making models and of the factors that affect crisis decision making and that the literature has so far identified. Conclusions are drawn about the significance of identifying of such factors and

LITERATURE REVIEW

In emergency situations, decision making requires non-traditional approaches and tools that are characterised by non-hierarchical structure and flexibility. The dynamic nature of crises imposes the examination of inter-sector and inter-agency collaboration. An example of such collaboration is the

Figure 1. Social Media-based Crisis Communication (Adapted from: Austin et al., 2012)



EMAC (Emergency Management Assistance Compact's) framework for the sharing of resources during and after crises between states. EMAC is a mutual aid agreement that aims to establish partnerships between states during large disasters. The agreement requires the collaboration between states first in the decision-making level (Kapucu & Garayev, 2011).

The factors that affect decision making in crisis emergencies are the complexity that arises from the severity of the situation and the involvement of several organisations in response operations (Bigley & Roberts, 2001), uncertainty caused by limited information in relation to the crisis situation (Cosgrave, 1996; Driskell & Salas, 1991); time pressure that results from urgency to make immediate decisions (Buchanan & O'Connell, 2006; Danielsson & Ohlsson, 1999; Lin & Su, 1998); stress caused by the severity of the crisis situation (Paton, 2003); risk that needs to be taken in order to decide on critical issues (Buchanan & O'Connell, 2006) and previous experience (Flin, 2001; Moynihan, 2008). Tools and techniques that improve decision making in crisis emergencies, training, decision support systems and simulations are suggested as techniques that enable the building of organizational capabilities and individual professional skills.

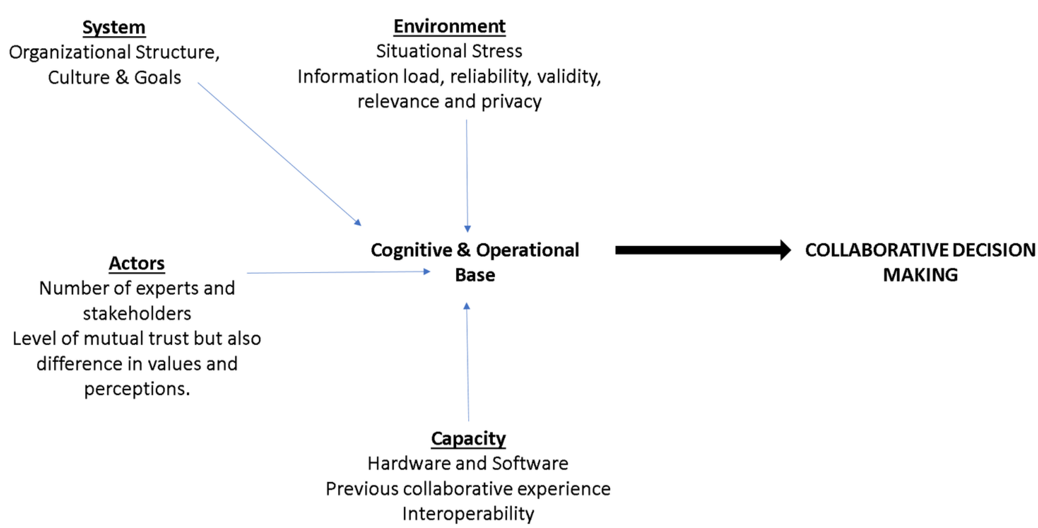
Kapucu and Garayev (2011) present a number of decision-making models that vary based on the factors that are included in the model. This variation can be expressed as two different continuums. The first continuum is the analytic-heuristic one which is based on data analysis and technical information (Smith & Dowell, 2000) and the second one is based on heuristic judgement which is the consequence of previous experience. Kapucu and Garayev (2011) mention a number of parameters related to the system, the environment, the actors, and the capacity in terms of Information and Communication Tools (ICTs) and the experience as elements of a cognitive and operational base that leads to collaborative decision making. These factors can be seen in Figure 2.

The need for an efficient way of crisis decision making is more immediate nowadays with the complexity that results from the use of advanced technology. For example, the power grid has become so complex and this complexity can result to major problems for its energy consumers. On the 4th of November 2006, the cruise ship Norwegian Perl was making its way on the German river Ems to the North Sea, thus requiring a shutdown of a 380KV power line across the river for safety reasons. This shutdown affected 15 million households across Europe (Lechner et al., 2016). Parsons et al. (2016) underline the significance of resilience towards disasters. Resilience is a theory for understanding the non-equilibrial dynamics of social-ecological systems with emphasis to the adaptability of social actors in relation to system dynamics of which natural hazards are part (Gunderson & Holling, 2002). Resilience can be used as a basis for the development of efficient crisis decision making techniques.

Cutter et al. (2003) developed the Social Vulnerability Index (SoVI) in order to study the vulnerability to various environmental hazards in US counties. There was an extraction of 42 variables that are related to wealth, age, race, ethnicity, housing and infrastructure characteristics. More factors were added to produce an overall SoVI score and were arrayed spatially to depict the vulnerability of US counties through time. The SoVi has been used for the development of integrated multi-hazard mapping (Tate et al., 2010). The Disaster Resilience of Place model (Cutter et al., 2008) describes disaster resilience as the connection between social, built and natural environments' conditions and the ability of a community to absorb hazard impacts. The model was tested for Florida counties and an overall community resilience score was produced (Cutter et al., 2010).

The MOVE approach to disaster vulnerability assessment was developed in Europe and includes a generic framework for integrated vulnerability assessment, steps for conducting such assessment and a tool box for assessment methods that includes indicators for vulnerability (Birkmann et al., 2013, European Commission, 2011). Indicators are specific to each vulnerability assessment and they also include other factors, such as social fragility, economic disruption, institutional arrangement, environmental status and demographics (European Commission, 2011). The IDB-IDEA programme is a holistic system of indicators that measure resilience of different countries. The system includes the Disaster Deficit Index, the Local Disaster Index, the Risk Management Index and the Prevalent Vulnerability Index (Cardona & Carreño, 2013). The latter index assesses vulnerability conditions through the measurement of the socio-economic fragility and the lack of social resilience especially across countries in Central and South America (Cardona, 2005).

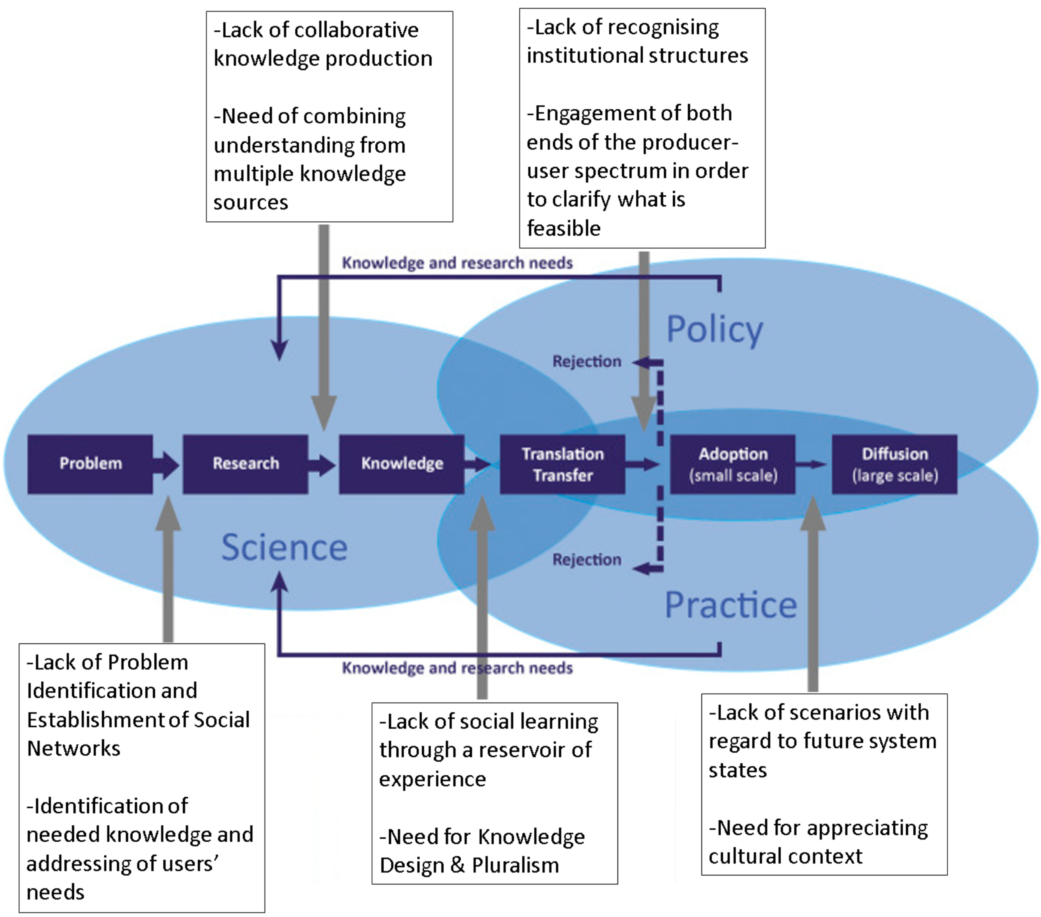
Figure 2. Factors that affect Collaborative Decision Making [Adapted from: Kapucu & Garayev, 2011]



Knowledge is important during crisis situations, however there is a deficit that results by the assumption that scientific knowledge is the only credible knowledge. This assumption however may overcome the fact that scientific knowledge may be embedded to larger systems of power and cultural dynamics (Spiekermann et al., 2015). There are multi-dimensional challenges in the development of scientific knowledge around disaster management and their application for risk mitigation. In this case, there are issues related to pure research and implementation, such as institutional practices and literacy, but also issues related to the coordination of multiple scientific practices. The prediction and management of a hazard involves the study of that hazard's occurrence and behaviour (Neale & Weir, 2015).

As shown in Figure 3, in hazard research, there is ignorance of the institutional and constitutional constraints and also infrequent investigation of resilience and adaptive capacities and risk education is seldom highlighted (Kuhlicke et al., 2011). Deficits also exist in relation to practical applications of conceptual thinking in vulnerability assessment, the systemic underlying of vulnerability causes and the assessment of substantial costs for implementing vulnerability reduction (Newton & Weichselgartner, 2014). There is the need for integration between multi-scale disaster risk-reduction and appropriate decision-making processes into a holistic concept. In scientific research, the issue of assessing and communicating any uncertainty must be examined. In relation to the policy domain, attention should be provided to vulnerability, risk- and climate-related issues as well as to the governance structures

Figure 3. Needs and Suggestion for Science, Policy and Practice (Adapted from: Spiekermann et al., 2015)



of decisions. Both domains should provide arenas where knowledge can be combined, thus providing interfaces among scientists and stakeholders to promote feedback and communication verification (Spiekermann et al., 2015).

Sayegh et al. (2004) present a conceptual model of decision-making under crisis in which emotions play an important role. Emotions do not only contribute to good managerial decision making but they are also an essential element of the intuitive decision processes used in crises. The presented model proposes the mechanisms behind intuitive decision making through the emphasis of the role of emotion. In addition, it attempts to be a comprehensive model of decision-making during crisis situations. Figure 4 shows a number of components that participate in the intuitive decision making. The model shows the primary relationships among these components for the purpose of future conceptual development (Sayegh et al., 2004).

THE ATHENA PLATFORM: CRISIS DECISION MAKING IN PRACTICE

The ATHENA Platform is a Crisis Communication and Management System that enables the public to participate in an ethical way in the process of emergency communication in order to contribute to the security of the citizens in crisis situations and for Search and Rescue Operations. ATHENA makes use of social media (e.g. Facebook, Twitter) and high-tech mobile devices to efficiently and effectively collect, analyse and disseminate crisis information. The major elements of the ATHENA Platform are the ATHENA Crisis Mobile App, the ATHENA Crisis Command & Control Intelligence Dashboard (CCCID), the ATHENA Logic Cloud, and the ATHENA Crisis Information Processing Centre (CIPC).

The ATHENA Command Control & Intelligence Dashboard (CCCID) is characterised by a number of functionalities, such as the real-time monitoring of crisis situations through filtered social media and the geo-location of crisis incidents and the identification of key locations for medical aid (Figure 5).

The Crisis Mobile is a web service for crisis responders and citizens. It includes the ATHENA Citizen Reporter 'Point & Shoot' system and the Crisis Mobile Receiving Tools. The ATHENA Crisis Information Processing Centre (CIPC) includes the acquisition and pre-processing tools as well as the aggregation and analysis tools. The first set of tools includes a social media scanner, a citizen report streaming and recording centre, a speech recognition system, a filter system and a crisis taxonomy

Figure 4. Intuitive Decision-Making Components (Adapted from: Sayegh et al., 2004)

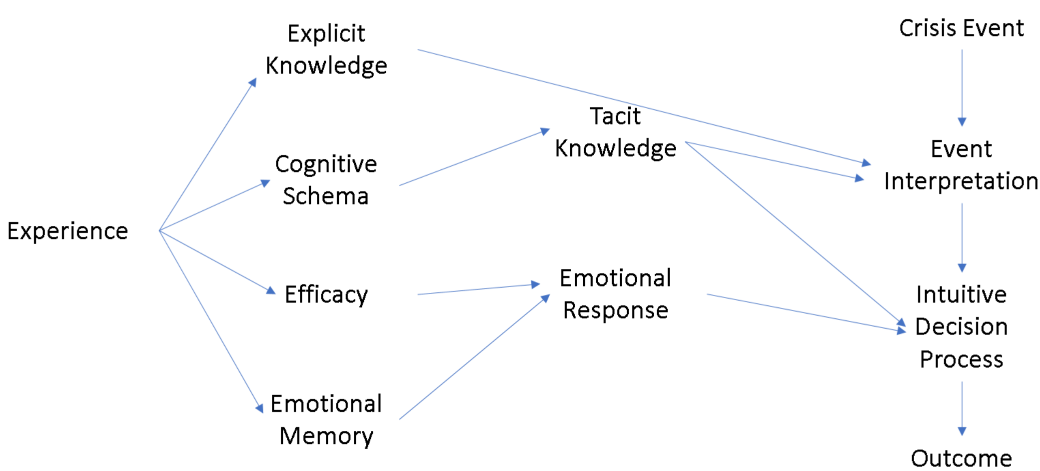
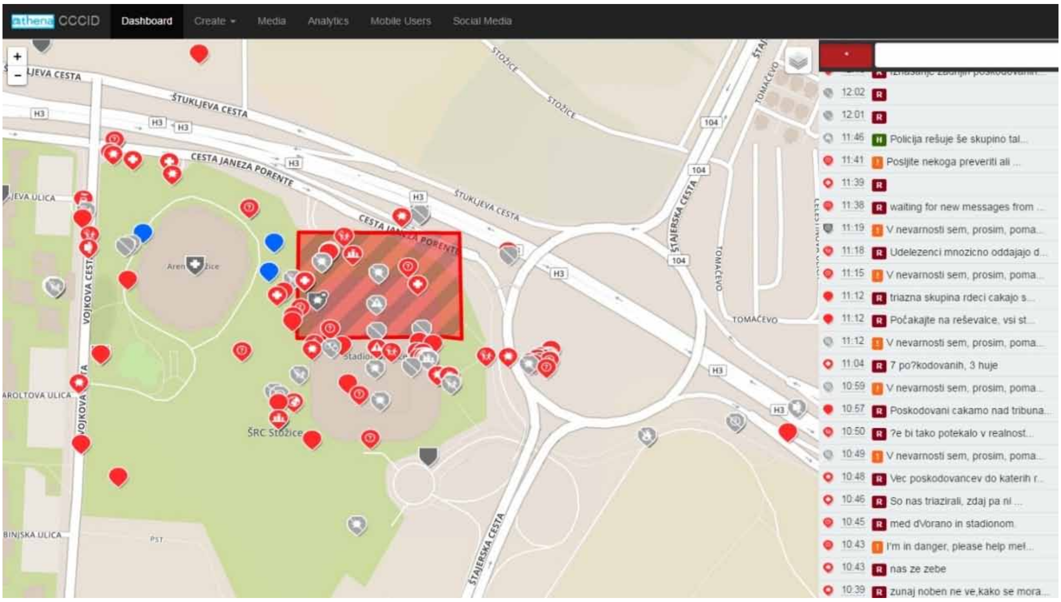


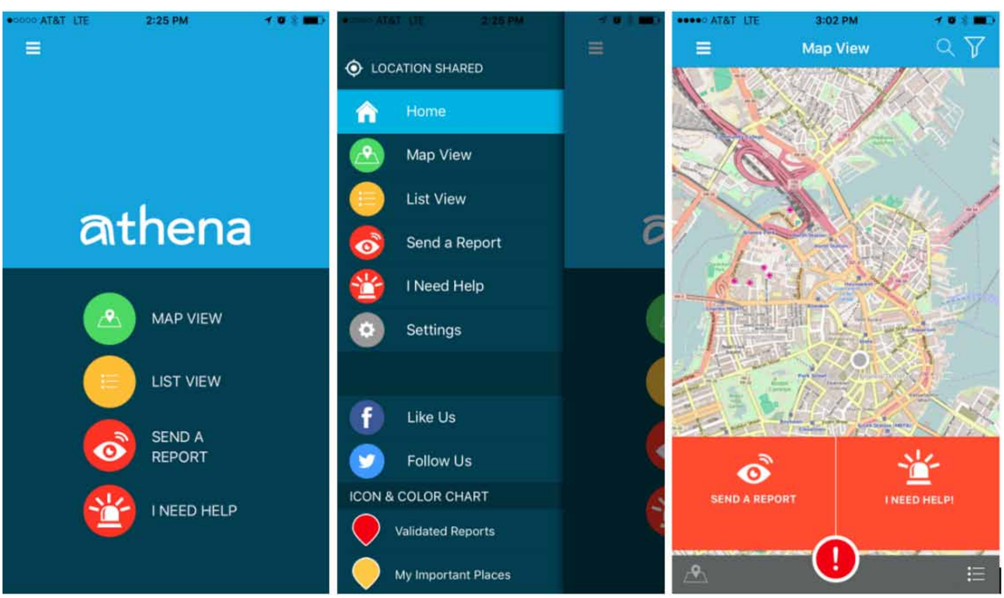
Figure 5. ATHENA CCCID Dashboard



system. The second set of tools includes a classification/clearance system, a Formal-Concept Analysis (FCA) system, a data fusion system, a credibility scoring system and a Sentiment Analysis tool. Figure 6 shows the ATHENA Crisis Interface.

The ATHENA CIPC allows the real-time acquisition of audio-visual messages from crisis-dedicated social media. Crisis taxonomies and Twitter hashtags are used for the filtering of the

Figure 6. ATHENA Crisis Interface

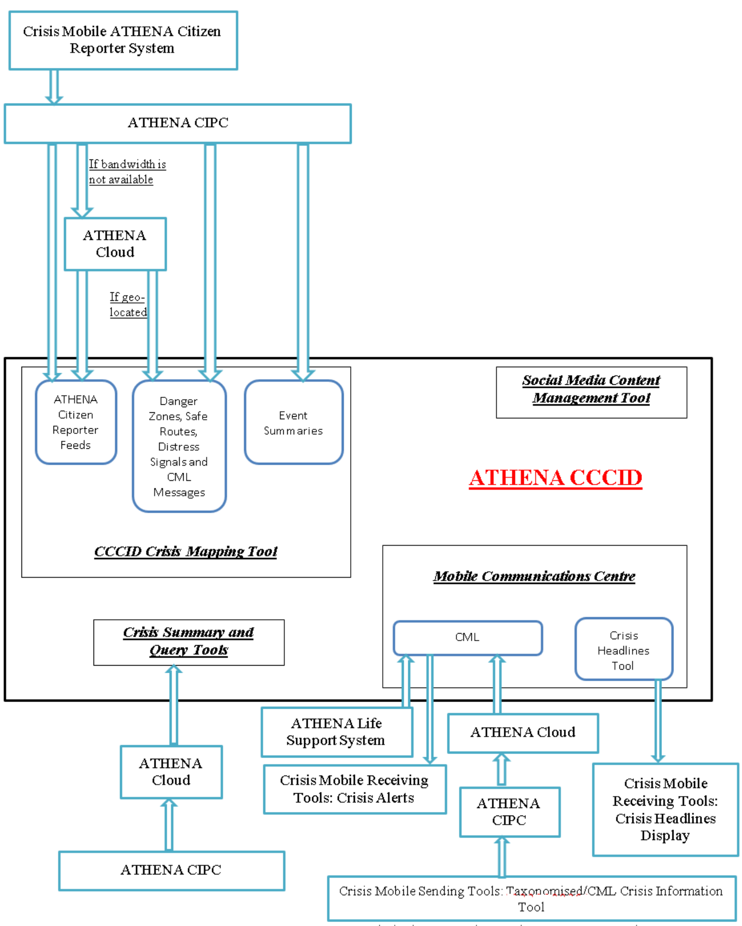


collected information. Text mining in the form of data fusion and Formal Concept Analysis (FCA) is used for data analysis.

The different elements and how they interact with each other are shown in Figure 7.

According to Figure 7, citizens can post live photos, videos or sound using the Crisis Mobile Citizen Reporter 'Point & Shoot' system. The posted messages are transferred to the ATHENA CIPC Citizen Report Streaming/Recording Centre. If there is available bandwidth, the messages will be transferred to the ATHENA CCCID. If there is not available bandwidth, then the messages are stored in ATHENA Cloud and if geo-located, they are then displayed to the ATHENA CCCID Crisis Map and/or to the ATHENA CCCID Crisis Summary and Query Tools. When the citizens use the Crisis Mobile Sending Tools Taxonomised/CML Crisis Information Tool, they can send text-based messages using a crisis taxonomy and/or Crisis Management Language (CML) selection/menu system. The message is transferred to the ATHENA CIPC and since they are text messages, they will be filtered using Natural-Language Processing. The filtered messages are then analysed by the ATHENA CIPC Aggregation & Analysis Tools for credibility scoring and sentiment analysis purposes. After the filtering, the messages are stored in the ATHENA Cloud. The messages are then displayed in the ATHENA CCCID Mobile Communications Centre. The police/LEAs/First responders can use the CML button to send messages to the Crisis Mobile Receiving Tools Crisis Alerts. Furthermore, they can use the Crisis Headlines Tool in order to populate and manage the Crisis Headlines Display.

Figure 7. ATHENA Platform Elements and their interconnections



COMPUTATIONAL TOOLS FOR COLLECTING AND EVALUATING HUMAN RESPONSE IN THE ATHENA PLATFORM

The ATHENA Platform is characterised by a number of services that affect the way crisis decision making is realised. Examples are the use of Social Media, Sentiment Analysis and Concept Extraction. These services are presented in detail below.

Map-Based Interfaces

Map-based interfaces are used for the display of crisis-related information. These interfaces include a PC-version for Command and Control and a Mobile version for the public and First Responders. The main characteristic of map-based interfaces is the 'map-pins' that are associated with specific crisis information. There is automatic aggregation of any information concerning the same even so that information overload is avoided.

Crisis Information Acquisition Tools

ATHENA uses a number of tools to acquire crisis information. The acquisition of crisis information can be distinguished to data reception and posting. Data posting tools include the ATHENA Citizen Reporter 'Point & Shoot' system which is used to stream live audio-visual material to the ATHENA Crisis Information Processing Centre. GPS and temporal information will be included in the data stream. A Crisis Taxonomy and/or Crisis Management Language (CML) are used in order for the user to send reports or requests for help.

The ATHENA Life Support System provides emergency messaging in the case when land lines and cell communications are disabled. If land lines or emergency numbers are disabled, the cell/Internet-enabled communications will allow geo-located, time-stamped requests for help to be sent from citizens to the CCCID Mobile Communications Centre.

Data reception tools include the mobile version of the ATHENA Crisis Map. Crisis Alerts are also used for the acquisition of information by citizens from the CCCID Mobile Communications Centre. These alerts include different CML messages, warnings, and instructions based on user, location and area. The Crisis Headlines Display is a continuous moving-banner display of current crisis news and progress information. There are also links to ATHENA-dedicated Crisis Social Media (Facebook, Twitter).

Sentiment Analysis

Sentiment Analysis uses automated processes to analyse real-time digital content in order to analyse the emotional meaning of the authors. These processes provide a detailed break-down of texts based on which visualizations are created and the overall expressed sentiment in the target text is clarified. ATHENA offers a suite of credibility assessment or scoring tools. Sentiment analysis is realised through a rule-based model which is similar to the model used in categorisation. A number of sentiment-related terms are specified representing either positive or negative sentiment and they are combined with Boolean rules.

Crawling and Processing Data from Social Media

In ATHENA, the two main sources of Social Media data are Twitter and Facebook. Twitter is one of the key sources of data during a crisis. The type of data included in a tweet are the text, the image, the video, the links and its hashtags. Twitter crisis data are extracted through the Twitter Search API. This API focuses on returning a subset of the tweets that match a particular query and a large number of metadata associated with a specific tweet. These metadata include spatial and temporal information but also the number of retweets, the number of favourites and a list of hashtags. Twitter allows users to construct more complex queries in order to extract more specific information.

The ATHENA Platform uses a real-time social media scanning system that is based on crisis taxonomies and crisis hash-tag syntaxes in order to detect and acquire information from the social media. The scanner collects citizen contributions from ATHENA crisis-dedicated social media. Photographs, video and audio recordings are collected along with text-based information. The collected information is fed into the CIPC Filter System in order for any noise to be removed.

Concept and Contextual Extraction

Concept and contextual extraction is the process of identifying features included in a document. These may be keywords, sentence constructs or even relationships between these features as defined by Boolean rules. Concept Extraction is the process of identifying relationships among terms. Concept Extraction is very useful for Social Media data because of the wide variety of terms and spellings that can refer to the same entity. The reduction of these entities to a single term streamlines data analysis. Contextual extraction is a similar process to concept extraction. The rule composition and the data extracted are more complex in structure and they are called 'facts'. The 'facts' are the outcome of the discovery of the relationship between two concepts.

Content Categorization

Categorisation is the process of analysing and categorising the content of a document based on a series of pre-defined rules. In ATHENA, there can be assignment of the same document to many different categories if its content matches numerous, different categories. The SAS Content Categorization Studio offers functionalities for automatic rule generation, rule writing and statistical categorisation. A pre-defined taxonomy of documents must be imported into SAS.

Formal Concept Analysis (FCA)

Formal Concept Analysis (FCA) is a data technology that is used for the visual analysis of large-scale data. Specifically, FCA is a conceptual clustering method which simultaneously clusters objects and their description. Furthermore, it computes efficiently association rules. The central notion of FCA is the Concept Lattice. This notion is based on concepts and conceptual hierarchies. FCA is based on the identification of binary relationships between objects and attributes indicating which object has which attribute. Conceptual relationships are then presented for data matrices which assign attribute values to each of the given objects. Finally, a mathematical model for conceptual knowledge systems is developed. This model allows us to study mathematically conceptual knowledge (Wille, 1992). A set of freely available FCA tools can be used. These are the context creator FcaBedrock and the concept miner InClose (Andrews & Orphanides, 2010).

Credibility Scoring

Credibility scoring is used in ATHENA for validating or rejecting incoming reports from users. The credibility assessment part of the ATHENA CIPC uses the decisions made by ATHENA operators in relation to the validity or non-validity of crisis data coming from various sources (e.g. social media, the ATHENA Mobile App). Two machine learning classification algorithms, decision trees and logistic regression, are used to provide classification of new report. The two most significant examples of decision tree learning algorithms are ID3 and C4.5. Logistic regression is a statistical process in which data are fitted to a logistical curve in order for the probability of the occurrence of an event to be predicted. Logistic regression uses a number of variables as predictors which can be categorical or numerical.

TESTING OF THE ATHENA PLATFORM

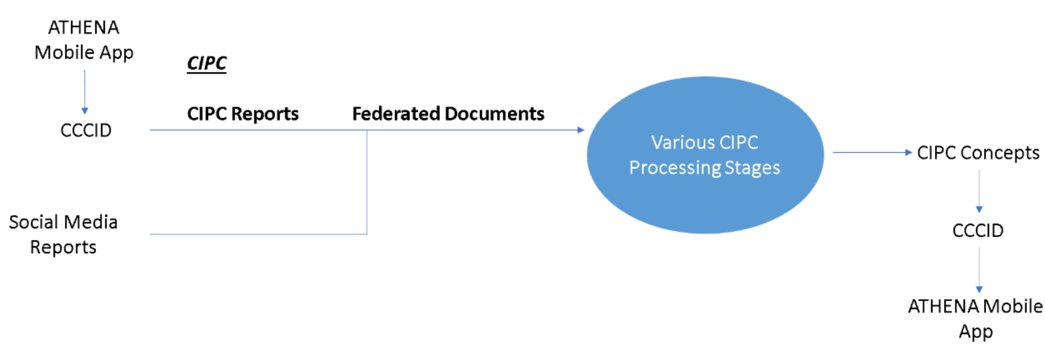
The ATHENA Platform was tested three times in three different locations at different consecutive times. Each exercise aimed to testing the progress of the development of the different functionalities of the ATHENA Platform under different crisis situations. The first exercise was realized in Izmir, Turkey and it included a number of phases, such as the familiarisation phase, the deployment of the system to various locations around Izmir, the sending and receiving of messages and the collection of feedback. During the exercise, the participants were instructed to do specific operations, such as opening reports associated with a specific location by clicking on the pin located at it and identify locations of particular danger. The second exercise took place in Ljubljana, Slovenia and it was focused on a natural disaster scenario. This exercise incorporated the use of the ATHENA Logic Cloud (also known as Decentralised Intelligence Processing Framework). The first exercise followed a more structured approach while the second exercise provided the users with more autonomy so that clear identification of user needs is achieved. The final ATHENA prototype testing exercise took place at West Yorkshire Police's Carr Gate training complex in Wakefield, United Kingdom. The focus of the final exercise was to test the performance of the system overall and to establish how well it met the requirements of the different sets of users. The final exercise is characterised by the large variety of scenarios in comparison to the other two exercises that cover the simulation of public incidents that include weapons, a bus attack, a potential terrorist incident and the case of an 'at risk' vulnerable person.

The users in the exercises are split into two categories: Citizen Users and Trusted Users. The Trusted User category was further broken down into Tier 1 Trusted Users which include first responders and other professionals and Tier 2 Trusted Users which include utility controllers, official volunteers, and credible community voices. There is also the CCCID Controller who sends and receives messages via the ATHENA dashboard system.

In order to comprehend how the different functionalities of the ATHENA Platform clarify the different factors that affect crisis decision making, the functionalities of crisis data categorisation and sentiment analysis are presented. Data enters the CIPC from the ATHENA CCCID or via the ATHENA CCCID from the ATHENA Mobile App or via the SAS Information Retrieval Studio (IRS) and/or social media crawlers. A component called OSINT Store is used by the CIPC and it is used for the capturing, the maintenance and the processing of crisis documents (Figure 8).

As crisis reports come into the ATHENA CCCID, they are transformed into a specific format such as XML and JSON. This process results in federated documents. After the federation, categorisation occurs. In this case, multiple categories from the crisis taxonomy are implemented and the output from this stage is used to filter non-crisis-relevant documents. If a document does not match any crisis, it may not be crisis-relevant. Further context in relation to the crisis documents is achieved through

Figure 8. ATHENA Crisis Report Processing



entity extraction which is realised against the crisis entity taxonomy. These entities are necessary in order to improve the aggregation of information collected by the crisis documents. Sentiment analysis is then performed in order to acquire structured viewpoints on the sentiment displayed in the report towards various entities.

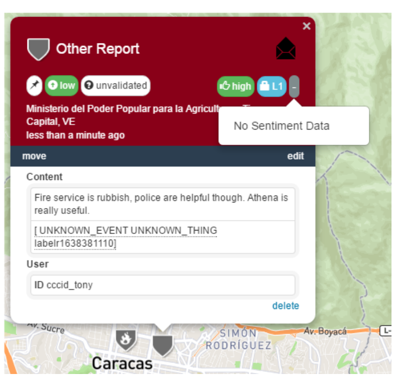
The ATHENA Mobile App is used for the collection of crisis data. These are the public user reports, the trusted user tier-2 reports that include reports from utilities controllers, official volunteers, and professionals from local resilience forums and other identified credible community voices, and the trusted user tier-1 reports that include reports from first responders and from the operational, tactical and strategic command of the Police. Data from the ATHENA Mobile App include metadata such as Report text, Report Image, Report video, Report audio, Report geo-location, Report tag, Report timestamp and User Type.

After a crisis report has been submitted, it is the stored on the ATHENA Mobile App back-end server. The ATHENA CCCID regularly polls this server for new and updated reports. Within the CIPC, the SAS IRS pipeline is responsible for content categorisation. Entities are detected and classified hierarchically so that a crisis taxonomy is developed. Each category in the crisis taxonomy is preceded by the text 'Top/Types of Crisis'. This allows detected categories to be represented in a tree structure providing both high-level and more specialised categories. For example, in a large crisis, SAS IRS can detect the following categories: top/types of crisis/fire and top/types of crisis/transport/crash/crash-vehicle/crash-car. These categories are then normalized into key-value attributes.

The body of each crisis document in the ATHENA CIPC pipeline is subject to sentiment analysis. The process is realized using the SAS Sentiment Analysis Studio and the Information Retrieval Studio (IRS) plug-in. There is development of models in the Sentiment Analysis Studio and then uploading of them to the IRS. In the ATHENA Platform, sentiment is divided into two categories – overall sentiment and product/feature sentiment. Overall sentiment classifies the sentiment of a whole document while product/feature sentiment classifies sentiment towards specific entities and their attributes. Sentiment analysis is realised via a rule-based model which is similar to that used in the categorisation procedure. A number of sentiment-related terms are specified, and they represent either positive or negative sentiments. These are combined with Boolean rules in order to evaluate sentiment. In addition to outputting a positive/negative/neutral/unclassified sentiment tag, the sentiment value can be acquired in various scales from 0 to 100 where 0 is negative and 100 is positive. The ATHENA configuration for SAS Sentiment Analysis Studio currently defines a scale on -10 to 10, where anything between -2 and +2 is neutral. Figure 9 shows the case of a crisis report in which there are negative references for the Fire Service and positive for the police and the ATHENA Mobile App.

Once the report has been federated into the ATHENA CIPC processing pipeline, it will then be subjected to categorisation, entity extraction, sentiment analysis and formal concept analysis. Once

Figure 9. Crisis Reports for the Fire Service, Police and ATHENA



finished, the updated data will be polled by the ATHENA CCCID which will parse the sentiment value (if any) and update the report.

From Figure 10, it can be shown that the overall sentiment has a negative value.

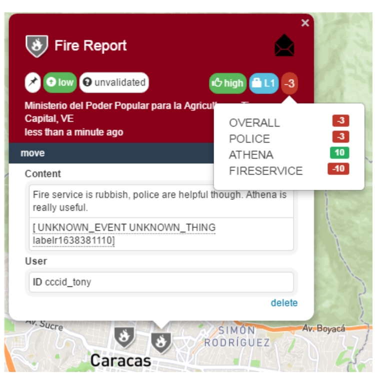
IDENTIFIED FACTORS THAT AFFECT ATHENA CRISIS DECISION-MAKING

Situational awareness is one of the factors that define the efficiency of the ATHENA Platform for crisis management operations. Situational awareness is related to the perception of elements within a volume of time and space. Most importantly, situational awareness considers the individual's social and cognitive state of comprehending what is happening during a crisis. It is important to understand the connection of situational awareness with command and control operations as it allows the comprehension of the conditions that characterize an event (Vieweg et al., 2010). Factors that define situational awareness are perception, comprehension, projection and temporal dynamics of an event. Situational awareness contributes to crisis sense-making. Inadequate crisis sense-making results to over-, under- or mis-estimations of emerging threats (Weick, 1988).

The testing scenarios and the phases within it represent the various stages of a crisis event and incorporate the stress, panic, fear and uncertainty of a large crisis. Stress affects individual and collective information processing. Specifically, under heavy stress, individuals focus only on the short term, narrow and deepen their span of attention, and are prone to irritability. Furthermore, stress affects the ability to recall necessary information and distracts the attention of decision makers from critical tasks. Crisis situations are characterised by intense negative emotions, most frequently associated with anxiety, such as fear and panic. Emotions of lower arousal, such as sadness or guilt, can also characterise a crisis situation (Bovey & Hede, 2001). Maitlis and Sonenshein (2010) argue that positive emotions can also be felt during crisis situations. These emotions are useful in increasing resilience against a crisis.

The ATHENA Platform is built in such a way so that situational awareness is achieved. Furthermore, the structure of the system and its functionalities can contribute towards reassurance and potentially positive emotion. This is achieved through a successful crisis communication between the public and a number of crisis experts. These experts achieve collaborative crisis knowledge production through the use of institutional structures. Also, it allows to clarify crisis information through the use of specific advanced data mining algorithms that consider public emotion during a large crisis. ATHENA uses filtering options that allow the identification and categorisation of crisis events. Furthermore, the ATHENA platform reduces the amount of citizens' anxiety during a crisis through the provision of a direct link to the emergency response teams. This results to the increment of the public's safety and the development of positive emotion. As Cameron et al. (2012) argue, emergency

Figure 10. ATHENA Sentiment Values



coordinators need a set of tools capable of managing the Social Media in order to address a number of needs such as the summarisation of crisis messages having awareness of aggregated content, the classification of high-value messages during a crisis incident, the pro-active identification of incidents and the forensic analysis of crisis incidents by analysing social media content. These are needs that are addressed by the ATHENA Platform.

CONCLUSION

Decision making is a multi-factorial process and especially for large crises, it is considered a very sensitive sequence of steps. Crises are dynamic situations and the exact identification of the factors that affect crisis decision making is very subtle. Crisis sense-making is difficult - especially when crisis stress can impede an individual's cognition. Emergency managers also have organisational and social constraints to contend with, such as policy making and institutional complexity constraints. The collection and analysis of crisis-related data is very significant for the resolution of large crisis situations. The ATHENA Platform is characterised by the combined use of advanced data algorithms mining with crisis-dedicated social media so that hidden crisis-related data patterns are identified. The importance of such a system is that it provides the necessary pro-activeness to the authorities in the handling of large crises. The system creates a sense of community among citizens as it allows online collaboration with the police and Law Enforcement Agencies (LEAs). Furthermore, the system is characterised by flexibility in the handling of data mining algorithms and the use of large amounts of crisis data. This flexibility allows the system to operate under different crisis situations as it considers a variety of different factors that change dynamically.

Social Media contribute significantly in the resolution of problems caused during and after a large crisis as they are able to provide large amounts of crisis-related data in a very small amount of time. The ATHENA Platform harnesses the power of Social Media through the use of crisis-dedicated Social Media pages. The analysis of the data provided by the citizens defines the flow of information within the system and between the system and its environment. The identification of different factors that affect crisis decision making and are directly connected to the progress of a crisis will lead to identification of similarities among different types of crises and this can result to a development of policies for the resolution of similar crises that take place in different areas. Overall, the identification of the different factors that characterise a crisis and of their degree of their impact in the progress of the crisis allows the development of a set of classified and clustered crisis big data that can indicate the different alternatives to the crisis decision maker and quantify their consequences.

REFERENCES

Andrews, S., & Orphanides, C. (2010). Analysis of large data sets using formal concept lattices. In *Proceedings of the 7th International Conference on Concept Lattices and Their Applications*, Seville, University of Seville (pp. 104-115).

Austin, L., Fisher Liu, B., & Jin, Y. (2012). How Audiences Seek Out Crisis Information: Exploring the Social-Mediated Crisis Communication Model. *Journal of Applied Communication Research*, *40*(2), 188–207. doi:10.1080/00909882.2012.654498

Bigley, G. A., & Roberts, K. H. (2001). The incident command system: High reliability organizations for complex and volatile task environments. *Academy of Management Journal*, *44*(6), 1281–1299. doi:10.2307/3069401

Billings, R., Milburn, T., & Schaalman, M. (1980). A model of crisis perception: A theoretical and empirical analysis. *Administrative Science Quarterly*, *25*(2), 300–316. doi:10.2307/2392456

Birkmann, J., Cardona, O. D., Carreño, M. L., Barbat, A. H., Pelling, M., Scheiderbauer, S., & Welle, T. et al. (2013). Framing vulnerability, risk and societal responses: The MOVE framework. *Natural Hazards*, *67*(2), 193–211. doi:10.1007/s11069-013-0558-5

Bovey, W. H., & Hede, A. (2001). Resistance to organizational change: The role of cognitive and affective processes. *Leadership and Organization Development Journal*, *22*(8), 372–382. doi:10.1108/01437730110410099

Bram, J., Orr, J., & Rapaport, C. (2002). Measuring the effects of the September 11 attack on New York City. *Economic Policy Review*, 5-20.

Buchanan, L., & O'Connell, A. (2006). A brief history of decision-making. *Harvard Business Review*, *84*(1), 32–41. PMID:16447367

Cameron, M., Power, R., Robinson, B., & Yin, J. (2012). Emergency situation awareness from Twitter for crisis management. In *Proceedings of the 21st Annual Conference on World Wide Web Companion* (pp. 695–698). New York: ACM. doi:10.1145/2187980.2188183

Cardona, O.D. (2005) Indicators of Disaster Risk and Risk Management (Summary report).

Cardona, O. D., & Carreño, M. L. (2013). System of indicators of disaster risk and risk management for the Americas: recent updating and application of the IDB-IDEA approach. In J. Birkmann (Ed.), *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies* (pp. 251–276). Tokyo: United Nations University Press.

Cosgrave, J. (1996). Decision making in emergencies. *Disaster Prevention and Management: An International Journal*, *5*(4), 28–35. doi:10.1108/09653569610127424

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. *Global Environmental Change*, *18*(4), 598–606. doi:10.1016/j.gloenvcha.2008.07.013

Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social Vulnerability to Environmental Hazards. *Social Science Quarterly*, *84*(2), 242–261. doi:10.1111/1540-6237.8402002

Cutter, S. L., Burton, C. G., & Emrich, C. T. (2010). Disaster resilience indicators for benchmarking baseline conditions. *Journal of Homeland Security and Emergency Management*, *7*(1). doi:10.2202/1547-7355.1732

Danielsson, M., & Ohlsson, K. (1999). Decision making in emergency management: A survey study. *International Journal of Cognitive Ergonomics*, *3*(2), 91–99. doi:10.1207/s15327566ijce0302_2

Driskell, J. E., & Salas, E. (1991). Group decision-making under stress. *The Journal of Applied Psychology*, *76*(3), 473–478. doi:10.1037/0021-9010.76.3.473

European Commission. (2011). Assessing vulnerability to natural hazards in Europe: from principles to practice, A Manual on Concept, Methodology and Tools, European Commission Research and Innovation (Technical Report). Retrieved 16 May 2017 from http://www.move-fp7.eu/documents/MOVE_Manual.pdf

Flüeler, T. (2006). *Decision-making for complex socio-technical systems: Robustness from lessons learned in long-term radioactive waste governance*. Dordrecht, The Netherlands: Springer. doi:10.1007/1-4020-3529-2

Gunderson, L. H., & Holling, C. S. (Eds.). (2002). *Panarchy: understanding transformations in human and natural systems*. Washington, D.C.: Island Press.

Hymowitz, C. (2001) “Companies experience major power shifts as crises continue”, *Wall Street Journal*

Cardona, O.D. (2005). Inter-American Development Bank Program for Latin America and the Caribbean. Washington, DC (*Technical Report*). Retrieved 30 June 2017 from https://publications.iadb.org/handle/11319/4801

Irving, L. J., & Mann, L. (1977). *Decision Making: A Psychological Analysis of Conflict, Choice, and Commitment*. New York: The Free Press.

Janis, I. L., & Mann, L. (1977). *Decision making: A psychological analysis of conflict, choice and commitment*. New York: Free Press.

Kapucu, N., & Garayev, V. (2011). Collaborative Decision-Making in Emergency and Disaster Management. *International Journal of Public Administration*, *34*(6), 366–375. doi:10.1080/01900692.2011.561477

Kleinmuntz, B. (1990). Why we still use our heads instead of formulas? Toward an integrative approach. *Psychological Bulletin*, *107*(3), 296–310. doi:10.1037/0033-2909.107.3.296 PMID:2190252

Kuhlicke, C., Steinführer, A., Begg, C., Bianchizza, C., Bründl, M., Buchecker, M., & Faulkner, H. et al. (2011). Perspectives on social capacity building for natural hazards: Outlining an emerging field of research and practice in Europe. *Environmental Science & Policy*, *14*(7), 804–814. doi:10.1016/j.envsci.2011.05.001

Lechner, S., Jacometti, J., McBean, G., & Mitchison, N. (2016). Resilience in a complex world – Avoiding cross-sector collapse. *International Journal of Disaster Risk Reduction*, *19*(October), 84–91. doi:10.1016/j.ijdrr.2016.08.006

Lin, D.-Y. M., & Su, Y.-L. (1998). The effect of time pressure on expert system based training for emergency management. *Behaviour & Information Technology*, *17*(4), 195–202. doi:10.1080/014492998119409

Maitlis, S., & Sonenshein, S. (2010). Sensemaking in Crisis and Change: Inspiration and Insights from Weick (1998). *Journal of Management Studies*, *47*(3), 551–580. doi:10.1111/j.1467-6486.2010.00908.x

Moynihan, D. P. (2008). Learning under uncertainty: Networks in crisis management. *Public Administration Review*, *68*(2), 350–365. doi:10.1111/j.1540-6210.2007.00867.x

Neale, T., & Weir, J. K. (2015). Navigating scientific uncertainty in wildfire and flood risk mitigation: A qualitative review. *International Journal of Disaster Risk Reduction*, *13*(September), 255–265. doi:10.1016/j.ijdrr.2015.06.010

New York Metropolitan Transportation Council. (2002). Demographic and Socioeconomic Forecasting Post September 11th Impacts: Inventory of affected businesses: Their characteristics and aftermath. Retrieved 10 April 2017 from https://www.nymtc.org/portals/0/pdf/SED/TM%203.1_FINAL.pdf

Newton, A., & Weichselgartner, J. (2014). Hotspots of coastal vulnerability: A DPSIR analysis to find societal pathways and responses. *Estuarine, Coastal and Shelf Science*, *140*, 123–133. doi:10.1016/j.ecss.2013.10.010

Parsons, M., Morley, P., Marshall, G., Hastings, P., Glavac, S., Stayner, R., . . . Reeve, I. (2016) The Australian Natural Disaster Resilience Index: Annual project report 2016 (Technical Report). Bushfire and Natural Hazards CRC. Retrieved 20 March 2017 from http://www.bnhcrc.com.au/file/6482/download?token=ksD51rwv

Paton, D. (2003). Stress in disaster response: A risk management approach. *Disaster Prevention and Management*, *12*(3), 203–209. doi:10.1108/09653560310480677

Pearson, C. M., & Clair, J. A. (1998). Reframing crisis management. *Academy of Management Review*, *23*(1), 59–76.

Sayegh, L., Anthony, W. P., & Perrewé, P. L. (2004). Managerial decision-making under crisis: The role of emotion in an intuitive decision process. *Human Resource Management Review*, *14*(2), 179–199. doi:10.1016/j.hrmr.2004.05.002

Snowden, D. J., & Boone, M. E. (2007). A Leader’s Framework for Decision Making. *Harvard Business Review*, (November): 2007. PMID:18159787

Spiekermann, R., Kienberger, S., Norton, J., Briones, F., & Weichselgartner, J. (2015). The Disaster-Knowledge Matrix – Reframing and evaluating the knowledge challenges in disaster risk reduction. *International Journal of Disaster Risk Reduction*, *13*(September), 96–108. doi:10.1016/j.ijdrr.2015.05.002

Stern, E. (2003). *Crisis Decisionmaking: A Cognitive Institutional Approach*. Stockholm: Swedish National Defence College.

Stern, E. (Ed.). (2014). *Designing Crisis Management Training and Exercises for Strategic Leaders*. Stockholm: Elanders Sverige AB.

Tate, E., Cutter, S. L., & Berry, M. (2010). Integrated Multihazard Mapping. *Environment and Planning. B, Planning & Design*, *37*(4), 646–663. doi:10.1068/b35157

The Associated Press. (2001). Quick response by Port Authority staff averted more casualties. Jersey City, NJ: The Associated Press State and Local Wire.

Vieweg, S., Highes, A. L., Starbird, K., & Palen, L. (2010). Microblogging During Two Natural Hazards Events: What Twitter May Contribute to Situational Awareness. In *Proceedings of the 28th International Conference on Human Factors in Computing Systems (CHI 2010)*, Atlanta, GA, April 10-15 (pp. 1079-1088). doi:10.1145/1753326.1753486

Weick, K. E. (1988). Enacted Sense-making in Crisis Situations. *Journal of Management Studies*, *25*(4), 305–317. doi:10.1111/j.1467-6486.1988.tb00039.x

Wille, R. (1992, March-May). Concept lattices and conceptual knowledge systems. *Computers & Mathematics with Applications (Oxford, England)*, *23*(6-9), 493–515. doi:10.1016/0898-1221(92)90120-7

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